

COMPOSITIONS AND METHODS FOR
ENHANCING CORTICOSTEROID DELIVERY

Field of the Invention

- [1] Topical corticosteroids are useful for their anti-inflammatory, anti-pruritic and vasoconstrictive actions. Corticosteroids (or corticoids) are any steroids (lipids that contain a hydrogenated cyclopentoperhydrophenanthrene ring system) elaborated by the adrenal cortex (except sex hormones of adrenal origin) in response to the release of adrenocorticotrophin or adrenocorticotrophic hormone by the pituitary gland, or to any synthetic equivalent, or to angiotensin II. Corticosteroids include but are not limited to alclometasone dipropionate, amcinonide, amcinafel, amcinafide, beclamethasone, betamethasone, betamethasone dipropionate, betamethasone valerate, clobetasone propionate, chloroprednisone, clocortelone, cortisol, cortisone, cortodoxone, difluorosone diacetate, descinolone, desonide, defluprednate, dihydroxycortisone, desoximetasone, dexamethasone, deflazacort, diflorasone diacetate, dichlorisone, esters of betamethasone, flucetonide, flucloronide, fluorocortisone, flumethasone, flunisolide, fluocinonide, fluocinolone acetonide, flucortolone, fluperolone, fluprednisolone, fluoroandrenolone acetonide, fluocinolone acetonide, flurandrenolide, fluorametholone, fluticasone propionate, hydrocortisone, hydrocortisone butyrate, hydrocortisone valerate, hydrocortamate, medrysone, meprednisone, methylprednisone, methylprednisolone, mometasone furoate, paramethasone, prednisone, prednisolone, prednidone, triamcinolone acetonide, and triamcinolone.
- [2] Hydrocortisone was the first corticosteroid found to be topically effective. Other more potent glucocorticoids, which are a subset of corticosteroids that affect carbohydrate metabolism, inhibit corticotropin secretion, and possess pronounced anti-inflammatory activity, have since been developed. Currently, topical steroids are among the most frequently prescribed of all dermatological drug products.
- [3] It is believed that glucocorticoids exert their potent anti-inflammatory effects by inhibiting the formation of prostaglandins and other derivatives of the arachidonic acid pathway. It is known that glucocorticoids inhibit the release of phospholipase

A2, the enzyme responsible for liberating arachidonic acid from cell membranes, thus inhibiting the arachidonic acid pathway. Currently, it is believed that glucocorticoids inhibit phospholipase A2, in cells by directly inducing phosphorylation of the enzyme.

- [4] Steroids are commonly divided into two classes, fluorinated and nonfluorinated. Fluorinated steroids have been chemically modified to increase potency. These modifications, such as halogenation and methylation, can result in improved activity within the target cell and in decreased breakdown to inactive metabolites. These modifications can also lead to more systemic side effects. However, modification of the chemical structure of the steroid is not the only way to increase potency.
- [5] The potency of topical steroid preparations is strongly correlated to their absorption through the skin. Treatment of the skin prior to application of the topical steroid may also affect the absorption of the compounds into the skin. Treatments with keratolytics or with fat solvents (such as acetone) disrupt the epidermal barrier and increase penetration. Hydrating the skin has also been shown to increase the penetration of the corticosteroids.
- [6] Once absorbed through the skin, topical corticosteroids are handled through pharmacokinetic pathways similar to systemically administered corticosteroids. The potencies of corticosteroids vary greatly and it is a challenge to increase the potency of any particular steroid.

Background of the Invention

- [7] The clinical effectiveness of corticoids is related to four basic properties: vasoconstriction, antiproliferative effects, immunosuppression, and anti-inflammatory effects. Topical steroids cause the capillaries in the superficial dermis to constrict, thus reducing erythema. The ability of a given glucocorticoid agent to cause vasoconstriction usually correlates with its anti-inflammatory potency. Vasoconstrictor assays are used in the art and by the U.S. Food and Drug Administration for determining the potency of topical corticosteroid preparations. Topical glucocorticoid preparations have been divided in the field into seven classes

based on potency based on double-blind clinical studies and vasoconstrictor assays.
Class 1 includes the most potent, while class 7 contains the least potent.

- [8] The following glucocorticoid preparations were designated in Fitzpatrick, Dermatology in General Medicine, 5th edition, CD-ROM, 1999, Table 243-1, with the following classes.

[9] Table 1

| Corticosteroid Preparation | Corticosteroid | Class | Source |
|----------------------------|----------------------------|-------|---------------------------|
| Temovate® Cream 0.05% | Clobetasone propionate | 1 | Glaxo Wellcome |
| Temovate® ointment 0.05% | Clobetasone propionate | 1 | Glaxo Wellcome |
| Diprolene® cream 0.05% | Betamethasone dipropionate | 1 | Schering Corp. |
| Diprolene® ointment 0.05% | Betamethasone dipropionate | 1 | Schering Corp. |
| Psorcon® ointment | Diflorasone diacetate | 1 | Dermik Laboratories, Inc. |
| Cyclocort® ointment 0.1% | Amcinonide | 2 | Fujisawa |
| Diprolene® cream AF 0.05% | Betamethasone dipropionate | 2 | Schering Corp. |
| Diprosone® ointment 0.05% | Betamethasone dipropionate | 2 | Schering Corp. |
| Elocon® ointment 0.1% | Mometasone furoate | 2 | Schering Corp. |

| | | | |
|--------------------------------|-------------------------------|---|-------------------------------|
| Florone® ointment 0.05% | Diflorasone diacetate | 2 | Dermik |
| Halog® cream 0.1% | Halcinonide | 2 | Westwood-Squibb |
| Lidex® gel 0.05% | Fluocinonide | 2 | Medicis Pharmaceuticals Corp. |
| Lidex® cream 0.05% | Fluocinonide | 2 | Medicis Pharmaceuticals Corp. |
| Lidex® ointment 0.05% | Fluocinonide | 2 | Medicis Pharmaceuticals Corp. |
| Maxiflor® ointment 0.05% | Diflorasone diacetate | 2 | Allergan Herbert |
| Topicort® cream 0.25% | Desoximetasone | 2 | Medicis Pharmaceuticals Corp. |
| Topicort® gel 0.05% | Desoximetasone | 2 | Medicis Pharmaceuticals Corp. |
| Topicort® ointment 0.25% | Desoximetasone | 2 | Medicis Pharmaceuticals Corp. |
| Aristocort A® ointment 0.1% | Triamcinolone acetanide | 3 | Fujisawa |
| Cutivate® ointment 0.005% | Fluticasone propionate | 3 | Glaxo Wellcome |
| Cyclocort® cream 0.1% | Amcinonide | 3 | Fujisawa |
| Cyclocort® Lotion 0.1% | Amcinonide | 3 | Fujisawa |
| Diprosone® cream 0.05% | Betamethasone dipropionate | 3 | Schering Corp. |
| Florone® cream 0.05% | Diflorasone diacetate | 3 | Dermik |
| Halog® ointment 0.1% | Halcinonide | 3 | Westwood-Squibb |

| | | | |
|--------------------------|----------------------------|---|-------------------------------|
| Lidex® E cream 0.05% | Fluocinonide | 3 | Medicis Pharmaceutical Corp. |
| Maxiflor® cream 0.05% | Diflorasone diacetate | 3 | Allergan Herbert |
| Valisone® ointment 0.1% | Betamethasone valerate | 3 | Schering Corp. |
| Cordran® ointment 0.05% | Flurandrenolide | 4 | Oclassen |
| Elocon® cream 0.1% | Mometasone furoate | 4 | Schering Corp. |
| Kenalog® cream 0.1% | Triamcinolone acetonide | 4 | Westwood-Squibb |
| Synalar® ointment 0.025% | Fluocinolone acetonide | 4 | Medicis Pharmaceuticals Corp. |
| Westcort® ointment 0.2% | Hydrocortisone valerate | 4 | Westwood-Squibb |
| Cordran® cream 0.05% | Flurandrenolide | 5 | Oclassen |
| Cutivate® cream 0.05% | Fluticasone propionate | 5 | Glaxo Wellcome |
| Diprosone® lotion 0.05% | Betamethasone dipropionate | 5 | Schering Corp. |
| Kenalog® lotion 0.1% | Triamcinolone acetonide | 5 | Westwood-Squibb |
| Locoid® cream 0.1% | Hydrocortisone butyrate | 5 | Ferndale |
| Synalar® cream 0.025% | Flucinolone acetonide | 5 | Medicis Pharmaceuticals Corp. |
| Valisone® cream 0.1% | Betamethasone valerate | 5 | Schering Corp. |

| | | | |
|---|----------------------------|---|-------------------------------|
| Westcort® cream 0.2% | Hydrocortisone valerate | 5 | Westwood-Squibb |
| Aclovate® cream 0.05% | Alclometasone dipropionate | 6 | Glaxo Wellcome |
| Aclovate® ointment 0.05% | Alclometasone dipropionate | 6 | Glaxo Wellcome |
| Aristocort® cream 0.1% | Triamcinolone acetonide | 6 | Fujisawa |
| Desowen® cream 0.05% | Desonide | 6 | Galderma |
| Synalar® solution 0.01% | Fluocinolone acetonide | 6 | Medicis Pharmaceuticals Corp. |
| Synalar® cream 0.01% | Fluocinolone acetonide | 6 | Medicis Pharmaceuticals Corp. |
| Tridesilon® cream 0.05% | Desonide | 6 | Miles |
| Valisone® lotion 0.1% | Betamethasone valerate | 6 | Schering Corp. |
| Topicals with hydrocortisone, dexamethasone, flumethasone, prednisolone, and methylprednisolone | | 7 | |

[10] All percentages given are weight percentages unless otherwise noted.

[11] Although there is no significant difference between potencies within Class 2, within Class 1 Temovate® cream or ointment is significantly more potent than Class 1 Diprolone® cream or ointment of Schering and Class 1 Psorcon® ointment of Dermik Laboratories, Inc.

- [12] Several factors such as the vehicle, the integrity of the epidermal barrier, and the use of occlusive dressings affect the percutaneous absorption and resulting potency of corticosteroids regardless of the intrinsic potency of the glucocorticosteroid (or glucocorticoid) molecule. Further, inflammation and/or other disease processes in the skin increase percutaneous absorption.

- [13] The vehicle in which the corticoid is incorporated may be as important as the corticoid molecule itself in determining the potency of a given formulation because the vehicle affects the amount of corticoid that is released in any given period of time, and its absorption. In many corticosteroid compositions, the vehicle is as much as 99% of the total composition. Very occlusive vehicles, such as ointments (water-insoluble mixtures of oil and petrolatum), increase the corticosteroid effect because they provide increased hydration of the stratum corneum and increase the skin's permeability. By covering the skin with an occlusive dressing such as plastic wrap, this effect can be heightened as much as 100-fold. The solubility of the corticoid in the vehicle also affects penetration into the skin.

- [14] Creams, which are suspensions of oil in water, have also been used as vehicles for corticosteroids. The compositions of creams vary and are far less greasy than ointments but do not provide the same degree of hydration to the skin, and therefore may not have as high penetration as ointments. Lotions, which are suspensions of oil in water and are similar to creams, are vehicles which include agents to help solubilize the corticosteroids. Solutions have been used as vehicles and are water based with propylene glycol. Gels are solid components at room temperature but melt on the skin. Lotions, gels and solutions have less penetration than ointments.

- [15] Many vehicles for corticosteroids include propylene glycol for dissolving the corticosteroid in the vehicle. In general, compositions that contain higher amounts of propylene glycol tend to be more potent.

- [16] Vehicles are so important in the potency of corticosteroids that different formulations containing the same amount of the same corticosteroid often are in different potency classes. For example, commercially available preparations of 0.05% betamethasone dipropionate are classified as having Class 1, Class 2 or Class 3 potency, depending on their vehicles (as seen in Table 1).

Summary of the Invention

- [17] The present invention comprises a novel vehicle which is safe for topical application, stable, and provides increased potency for corticosteroid preparations, especially fluorinated corticosteroids.
- [18] An embodiment of the present invention delivers the corticosteroid in a vehicle that comprises a corticosteroid, and (a) at least two penetration enhancers, including propylene glycol, dimethyl isosorbide or diisopropyl adipate, (b) solvents and/or emulsifiers for the corticosteroid and optionally the penetration enhancers and (c) optionally, non-solvent/emulsifier ingredients. The vehicle has a ratio of a:(a+b) that is greater than or equal to 0.70, preferably greater than or equal to 0.80 and most preferably greater than or equal to 0.90 or 0.95.

Detailed Description of the Preferred Embodiments

- [19] The present invention enhances the potency of corticosteroid preparations with a vehicle comprising at least two penetration enhancers, including diisopropyl adipate, dimethyl isosorbide, propylene glycol, 1,2,6-hexanetriol, and benzyl alcohol. The corticosteroids with which this invention may be used include, but are not limited to, fluorinated corticosteroids.
- [20] Another embodiment of the present invention is a method for enhancing the potency of corticosteroids, preferably fluorinated corticosteroids. The corticosteroid is combined with two or more penetration enhancers (preferably propylene glycol and at least one other penetration enhancer), and one or more solvents and emulsifiers for the corticosteroid and optionally penetration enhancers, wherein the penetration enhancers are present in ratio to the total of the penetration enhancers, and solvents and emulsifiers of at least about 0.70, preferably at least 0.80 and most preferably 0.90 or 0.95. Optionally, one or more inactive ingredients may also be combined with the corticosteroid.
- [21] Another embodiment of the present invention is a method of delivering corticosteroids to skin, nails or hair, preferably mammalian skin, most preferably human, dog or cat skin. The corticosteroids are preferably fluorinated

corticosteroids. The corticosteroid is combined with two or more penetration enhancers, and one or more solvents and emulsifiers for the corticosteroid, wherein the penetration enhancers are present in ratio to the total of the penetration enhancers, and solvents and emulsifiers of at least about 0.70, preferably at least 0.85 and most preferably 0.90 or 0.95. Optionally, one or more inactive ingredients may also be combined with the corticosteroid.

- [22] As indicated above, this invention is broadly applicable to corticosteroids in general, and fluorinated corticosteroids in particular, most preferably fluocinonide or fluocinolone acetonide. The following examples show its application to preparations of fluocinonide, a commonly used fluorinated corticosteroid. Fluocinonide is a corticosteroid which is the 21-acetate ester of fluocinolone acetonide with the chemical name pregna-1,4-diene-3,20-dione,21-(acetyloxy)-6,9-difluoro-11-hydroxy-16, 17-[(1-methylethylidene)bis(oxy)]-, (6 α ,11 β , 16 α)-. Compositions containing 0.05% (all percentages are weight percentages) fluocinonide are commonly classified as Class 2.

Example 1

- [23] Experiments were conducted with embodiments of the present invention and several control compositions. Compositions were prepared and the investigator was blinded with respect to the compositions. Thirty-six healthy volunteers were enrolled for two-day trials. On day 1, a single application of approximately 10 milligrams of at least eight compositions was made to 1 cm² sites on the lower aspect of each volunteer's forearms in accordance with a computer generated randomization code. After applying the compositions, the sites were protected using a raised perforated guard. The guard was secured to the arm with a non-occlusive tape and the subjects were scheduled to return the following day after being instructed to keep the sites dry.
- [24] After approximately 16 hours of contact with the skin, the protective guards were removed and the compositions were removed from the test sites by gently washing with mild soap and water. Skin vasoconstrictor evaluations were performed on a four point scale (0-3) at approximately 18 hours after application.

[25] Scores for skin vasoconstriction were summed for each composition (each composition was applied to thirty-six volunteers and those thirty-six scores were summed). For each composition tested, the ratio of penetration enhancers (a) to the sum of penetration enhancers, and solvents and emulsifiers (a+b) was calculated (a:(a+b)). All of the compositions comprise 0.10% fluocinonide.

[26] **Table 2**

| Range of a:(a+b) | 1- 0.95 | 0.94- 0.90 | 0.89- 0.80 | 0.79- 0.70 | 0.69- 0.60 | 0.59- 0.50 |
|---|------------|---------------|---------------|---------------|---------------|---------------|
| Average of Summed Vasoconstrictor Scores | 93 | 85 | 71 | 72 | 62 | 58 |

[27] * means there were no samples with the range of 0.59 to 0.55.

[28] As seen in the above table, the average vasoconstrictor scores are significantly lower for ranges of $a:(a+b) < 0.70$. The corticosteroid preparations with average vasoconstrictor scores of 58 and 62 are significantly less potent than those preparations with average vasoconstrictor scores of 72 and higher. Scores of 62 and 58 are not significantly different. This magnitude of increase in vasoconstrictor scores is typical of an increase in class.

[29] Several control compositions (with 0.10% fluocinonide and no penetration enhancers, as defined below, were included) were also tested for their vasoconstrictor scores in the same manner. Therefore, the ratios of a:(a+b) are zero. The vasoconstrictor scores are 60.00 and 59.00, which are significantly lower than the present invention's embodiments' vasoconstrictor scores.

[30] Additionally, several other control compositions were tested for their vasoconstrictor scores ("vasoscores"). These compositions comprised 0.10% fluocinonide, and no diisoproyl adipate, propylene glycol or dimethyl isosorbide. Their vasoscores were 49.00, 47.00 and 44.00.

- [31] The experiments also included several Class 1 compositions as comparison points. Psorcon® ointment by Dermik Laboratories, Inc. of Collegeville, PA with 0.05% diflorasone diacetate had a vasoscore of 101. Ultravate® ointment by Westwood-Squibb of Evansville, IN with 0.05% halobetasol propionate had a vasoscore of 97, while Ultravate® cream by Westwood-Squibb with 0.05% halobetasol propionate had a vasoscore of 92.
- [32] In the ratio of (a): (a+b), penetration enhancers include at least two of: propylene glycol, diisopropyl adipate, dimethyl isosorbide, 1,2,6 hexanetriol, and benzyl alcohol (collectively referred to as "a"). The solvents and emulsifiers for the corticosteroid include one or more of dehydrated alcohol, alcohol (95% v/v) USP, 3-Cyclohexene-1-Methanol, α 4-Dimethyl-a-(4-Methyl-3-Pentenyl)-, Steareth-2, Steareth-21, citric acid, CPE-215, diisopropanolamine (1:9), DIPA/PG (1:9), ethoxydiglycol, Potassium hydroxide (10%), PEG-40 Stearate, PEG-7000, Polysorbate 60, potassium hydroxide (1%), propylene carbonate USP, propylene glycol 4, oleyl alcohol, sodium lauryl sulfate, sorbitan monostearate, sorbitan stearate, and 1,2,3-Propanetriol Ester (collectively referred to as "b").
- [33] The compositions optionally comprise non-solvent/emulsifier ingredients, such as Glyceryl Stearate (and) PEG-100 Stearate, carbopol 980, cyclomethicone NF, glyceryl monostearate, hydroxyethyl cellulose, hydroxypropyl cellulose, isopropyl myristate, methyl paraben NF, mineral oil, oleic acid NF, PEG-100 Stearate, petrolatum, propyl paraben NF, purified water, stearyl alcohol, white petrolatum, and white wax.
- [34] The combination of penetration enhancers used in the invention have a remarkable and unexpected result. Compounds using similar concentrations of a single penetration enhancer (e.g. propylene glycol as the sole penetration enhancer with 0.10% fluocinonide yielded vasoscores of 72.00, and 50.00, depending on the solvents, emulsifiers and non-solvent/emulsifier ingredients used) do not have similarly high vaso scores. Compositions with the combination of penetration enhancers and formula scores of less than 0.65 also have low vaso scores. Therefore the invention results in an unexpected increase in potency of the fluocinonide.

Example 2

[35] One embodiment of the present invention is detailed in the chart below.

[36] **Table 3**

| Component | %w/w | %w/w |
|--|------|------|
| Fluocinonide Micronized, USP | 0.1 | 0.1 |
| Propylene Glycol, USP | 70.0 | 74.9 |
| Dimethyl isosorbide | 15.0 | |
| Diisopropyl Adipate | | 3.0 |
| Isopropyl Myristate, NF | | 5.0 |
| 1,2,6 Trihydroxyhexane | | 2.5 |
| Carbopol 980 | 1.2 | 1.0 |
| Diisopropanolamine 85%: propylene glycol (1:9) | 1.2 | 1.0 |
| Citric Acid, USP | 0.01 | 0.01 |
| Purified Water, USP | 2.49 | 2.49 |
| Glyceryl | 2.5 | 2.5 |

| | | |
|--|-----|-----|
| monostearate | | |
| Glyceryl monostearate & PEG stearate | 7.5 | 7.5 |

Example 3

[37] Another embodiment of the present invention is detailed in the chart below.

[38] Table 4

| Component | %w/w | %w/w |
|--|------|------|
| Fluocinonide Micronized, USP | 0.1 | 0.1 |
| Propylene Glycol, USP | 66.8 | 69.9 |
| Dimethyl isosorbide | 5.0 | |
| Diisopropyl Adipate | | 2.0 |
| Isopropyl Myristate, NF | 5.0 | 5.0 |
| Carbopol 980 | 0.5 | 0.5 |
| Diisopropanolamine 85%: propylene glycol (1:9) | 0.5 | 0.5 |
| White Petrolatum, USP | 5.0 | 5.0 |
| Glyceryl | 6.0 | 6.0 |

| | | |
|---------------------------|-----|-----|
| monostearate | | |
| PEG 100 stearate | 6.0 | 6.0 |
| Stearyl alcohol, NF | 5.0 | 5.0 |
| Sodium Lauryl Sulfate, NF | 0.1 | |

- [39] It is to be understood that while the invention has been described in conjunction with the detailed description thereof, that the foregoing description is intended to illustrate and not limit the scope of the invention, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are evident from a review of the following claims.